

CLAIMS

What is claimed is:

1. A microelectromechanical apparatus for redirecting incident light, comprising:
 - (a) a substrate;
 - (b) a first electrostatic actuator formed on the substrate and comprising a first beam supported above the substrate for movement towards the substrate in response to a first actuation voltage provided to the first electrostatic actuator;
 - (c) a second electrostatic actuator comprising a second beam formed above the first electrostatic actuator and attached thereto, with the second beam being moveable towards the substrate in response to movement of the first beam, and with the second electrostatic actuator providing a further movement of the second beam towards the substrate in response to a second actuation voltage provided to the second electrostatic actuator; and
 - (d) a plate formed above the second electrostatic actuator and attached thereto, with the plate having a surface for reflecting the incident light to generate a reflected light component having a phase shift or a change in an angle of propagation which depends upon a movement of the plate produced by one or both of the first and second electrostatic actuators.
2. The apparatus of Claim 1 wherein the first beam is supported above the substrate by a single support post.
3. The apparatus of Claim 1 wherein the first beam is supported above the substrate by a plurality of support posts.
4. The apparatus of Claim 1 wherein the substrate comprises silicon.
5. The apparatus of Claim 1 wherein the first and second beams comprise different layers of polycrystalline silicon.
6. The apparatus of Claim 1 wherein the first and second beams are arranged end-to-end.
7. The apparatus of Claim 1 wherein the first and second beams are arranged side-by-side.

8. The apparatus of Claim 7 wherein the first electrostatic actuator further comprises a third beam supported above the substrate for movement towards the substrate in response to the first actuation voltage, with the second beam being located between the first and third beams and attached thereto.
9. The apparatus of Claim 8 wherein the second beam is attached to the first and third beams near a midpoint of each of the first and third beams.
10. The apparatus of Claim 8 wherein the second beam is attached to the first and third beams near an unsupported end of each of the first and third beams.
11. The apparatus of Claim 1 wherein the plate includes a mirror coating formed thereon.
12. The apparatus of Claim 1 wherein the first electrostatic actuator comprises a first electrode formed on the substrate beneath a portion of the first beam.
13. The apparatus of Claim 12 wherein the second electrostatic actuator comprises a second electrode formed on the substrate beneath a portion of the second beam.
14. The apparatus of Claim 1 wherein the first and second actuation voltages are identical and are simultaneously applied to the first and second electrostatic actuators.
15. A microelectromechanical apparatus for redirecting incident light, comprising:
 - (a) a substrate;
 - (b) a plate supported above the substrate and having a light-reflecting upper surface;
and
 - (c) a plurality of interconnected beams located beneath the plate to support the plate and to electrostatically move the plate towards the substrate, with the plurality of interconnected beams comprising three beams formed substantially parallel to the substrate, and with the three beams including a pair of beams formed from one or two layers of polycrystalline silicon and another beam formed from a different layer of polycrystalline silicon, and with each beam having at least one electrode located beneath the beam to urge the beam towards the substrate in response to an actuation voltage provided between the electrode and the beam to move the plate towards the substrate.
16. The apparatus of Claim 15 wherein the substrate comprises silicon.
17. The apparatus of Claim 15 wherein the three beams are arranged end-to-end.

18. The apparatus of Claim 15 wherein the three beams are arranged side-by-side.
19. The apparatus of Claim 15 wherein the plate includes a mirror coating formed thereon.
20. A microelectromechanical apparatus for redirecting incident light, comprising:
 - (a) a substrate;
 - (b) a plate supported above the substrate and having a light-reflecting upper surface; and
 - (c) a pair of electrostatic actuators formed above the substrate to support the plate for movement thereof, with the pair of electrostatic actuators comprising:
 - (1) a first electrostatic actuator further comprising a pair of spaced-apart beams with each beam being connected at one or both ends thereof to the substrate, and with a first electrode being formed beneath each beam to urge the plate towards the substrate in response to an electrostatic force of attraction produced between that beam and the first electrode therebeneath; and
 - (2) a second electrostatic actuator comprising another beam located above the pair of spaced-apart beams of the first electrostatic actuator and connected thereto and further being connected to the plate, and a pair of second electrodes formed beneath the beam of the second electrostatic actuator to further urge the plate towards the substrate in response another electrostatic force of attraction produced between that beam and at least one of the pair of second electrodes.
21. The apparatus of Claim 20 wherein the substrate comprises silicon, and each beam comprises polycrystalline silicon.
22. The apparatus of Claim 20 wherein the plate includes a mirror coating formed thereon.
23. The apparatus of Claim 20 wherein the movement of the plate produces a change in tilt angle of the plate.
24. The apparatus of Claim 20 wherein the movement of the plate produces a phase shift in a reflected portion of the incident light.

25. A microelectromechanical apparatus for redirecting incident light, comprising:
- (a) a substrate;
 - (b) a plate supported above the substrate and having a light-reflecting upper surface;
and
 - (c) a pair of electrostatic actuators attached to the substrate by a single support post to electrostatically move the plate towards the substrate, with the pair of electrostatic actuators comprising:
 - (1) a first electrostatic actuator further comprising a beam attached to the single support post near a midpoint of the beam, and with a pair of first electrodes being formed beneath the beam proximate to the single support post to urge the plate towards the substrate in response to an electrostatic force of attraction produced between the beam and at least one of the first electrodes located therebeneath; and
 - (2) a second electrostatic actuator further comprising a pair of beams located above the beam of the first electrostatic actuator and attached thereto at one end of each of the pair of beams, with another end of each of the pair of beams being attached to the plate, and with a second electrode being formed beneath each of the pair of beams proximate to the beam of the first electrostatic actuator to further urge the plate towards the substrate in response to another electrostatic force of attraction produced between at least one beam of the pair of beams and the second electrode located therebeneath.
26. The apparatus of Claim 25 wherein the substrate comprises silicon, and each beam comprises polycrystalline silicon.
27. The apparatus of Claim 25 wherein the plate includes a mirror coating formed thereon.
28. The apparatus of Claim 25 wherein the movement of the plate produces a change in tilt angle of the plate.
29. The apparatus of Claim 25 wherein the movement of the plate produces a phase shift in a reflected portion of the incident light.